CERES Energy Balanced and Filled (EBAF) TOA Edition 4 Update

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EBAF-TOA Ed2.8 (Current Version)

- Essentially a hybrid of:
  - Clouds & ADMs used in CERES SSF Ed2 (same as Ed3)
    => GEOS 4 (03/2000-12/2007), GEOS 5.2.1 (01/2008-)
    => MODIS Collection 4 (03/2000-04/2006) & 5 (05/2006-)
  - TOA fluxes determined using Ed3 calibration coefficients

- While input changes have minimal impact on all-sky TOA fluxes, they cause discontinuities in clear-sky TOA fluxes (through scene identification) and all-sky and clear-sky surface radiative fluxes.

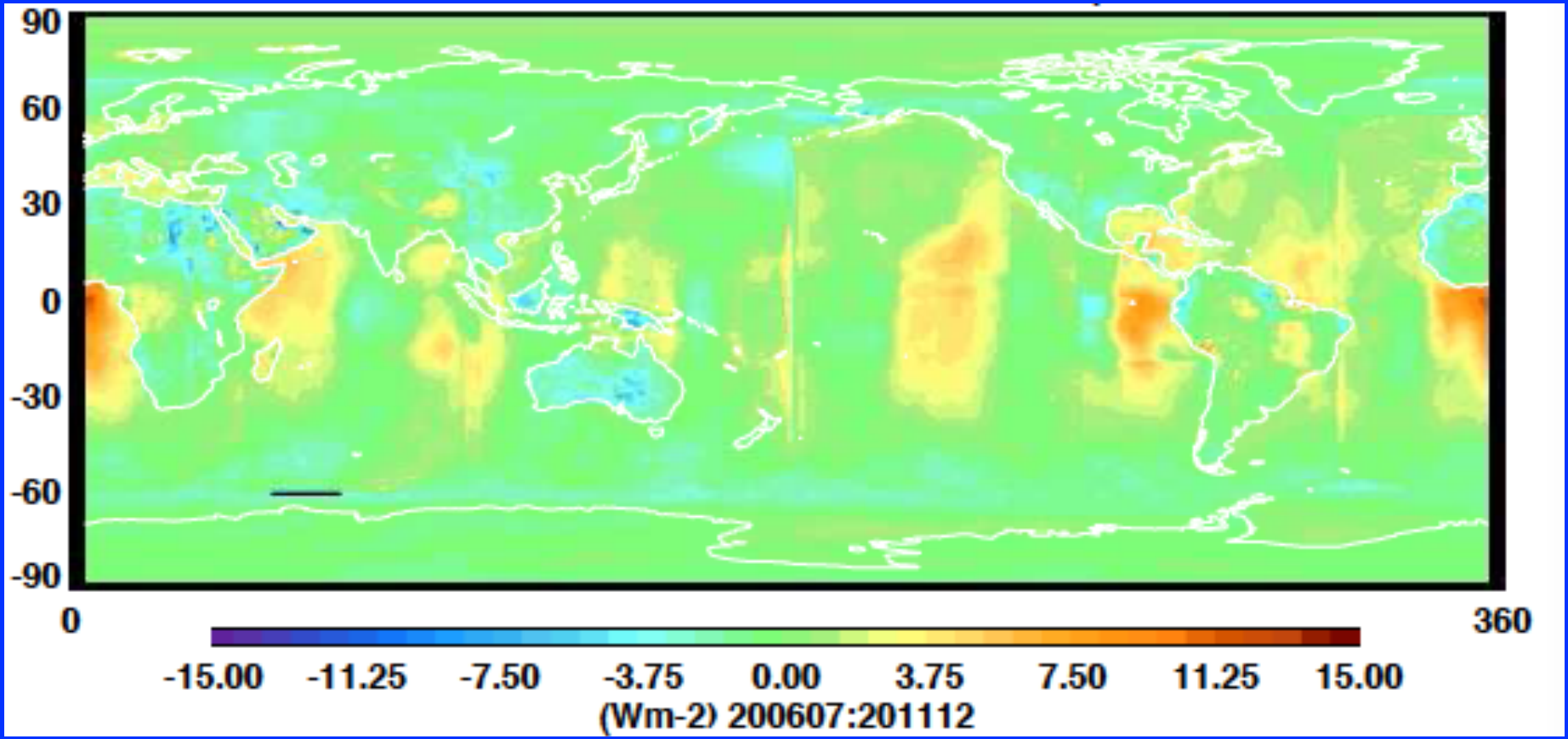
- Consequently, there's a spurious trend in TOA Cloud Radiative Effect.

- EBAF-SFC makes adjustments to minimize impact of input changes.

EBAF-TOA Ed 4.0 (All-Sky)

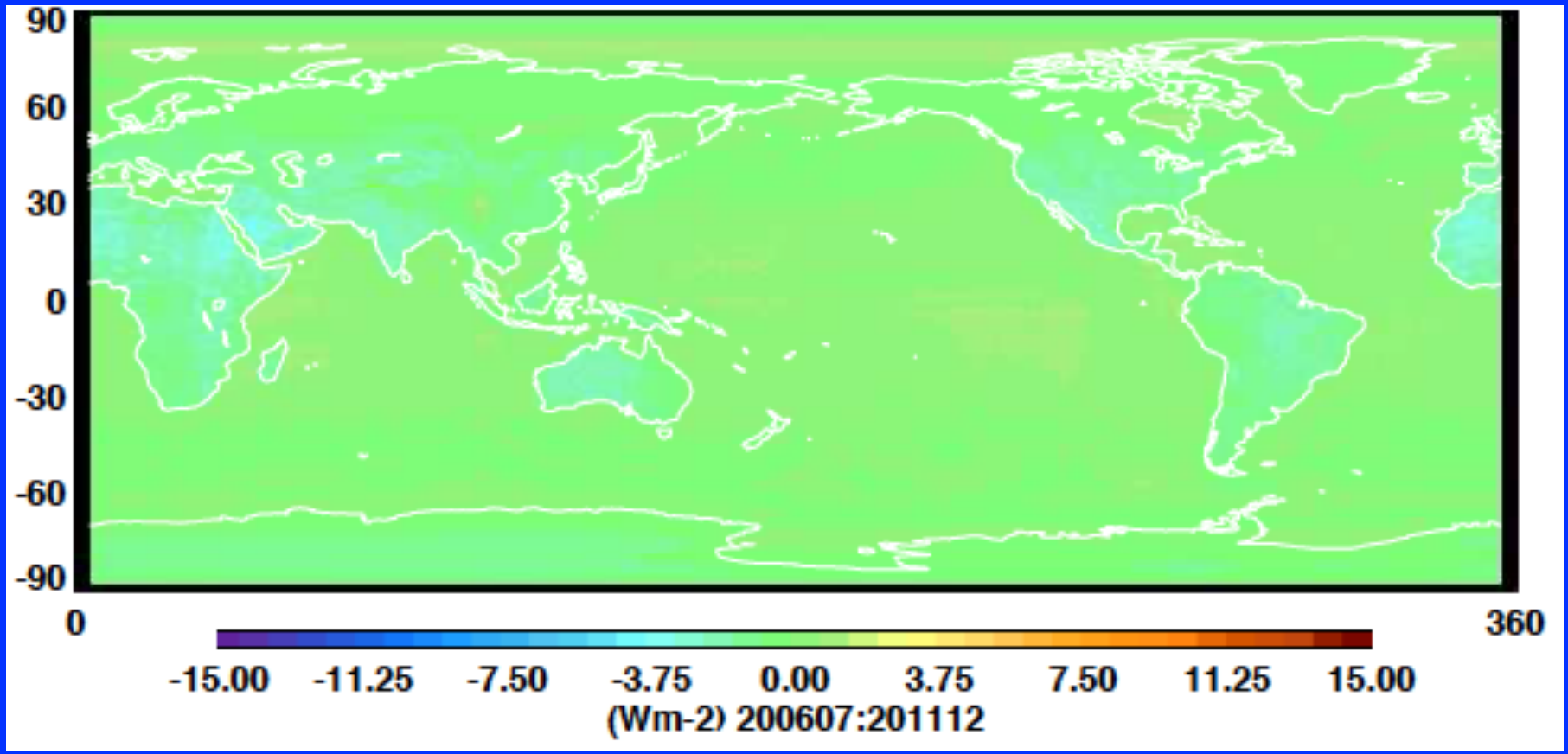
- Will incorporate all of the Ed4 algorithm improvements:
  - Improved instrument calibration
  - Cloud properties
  - ADMs
  - Time Interpolation and Space Averaging (with hourly GEOs)
  - Will be based upon consistent met assimilation (GEOS 5.4.1), MODIS radiances and aerosols (Collection5, until that gets superseded by C6)
  - GMT instead of local time
- TOA fluxes will be constrained using same approach as EBAF Ed2.8 (Argo constraint) but using 10 years of Argo instead of 5 years.
- Will provide some basic MODIS cloud properties (f, τ, p_{eff}) alongside TOA fluxes on ordering tool.

All-Sky SW TOA Flux Difference: Ed4 SYN1deg minus Ed3 SYN1deg (200607-201112; Terra+Aqua+GEO)

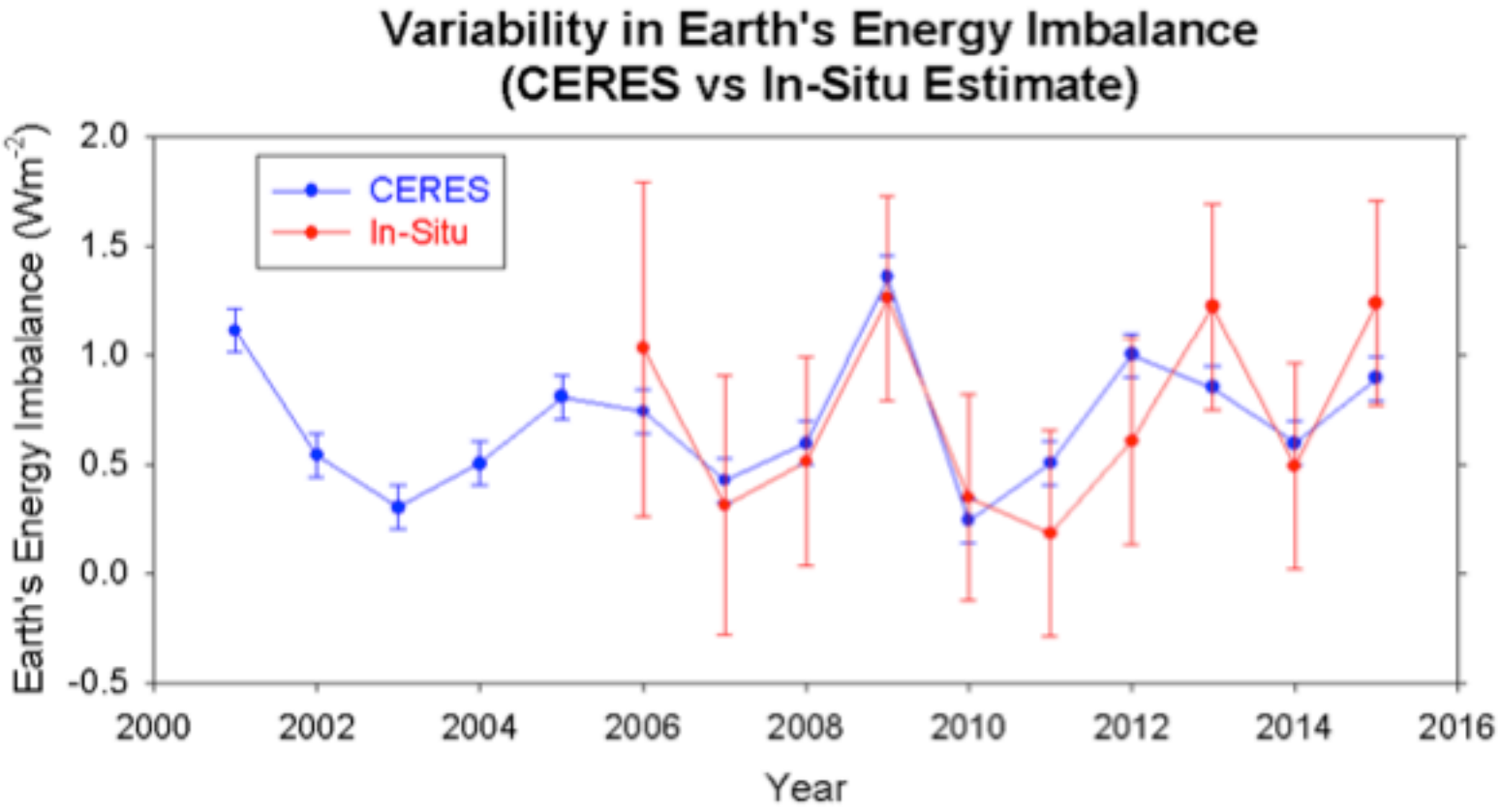


- Global mean difference = 0.3 Wm^{-2}
- Largest differences associated with use of 1 h vs 3 h geostationary instruments.
- EBAF-TOA Ed4: regional pattern of differences should be similar in magnitude.

All-Sky LW TOA Flux Differene: Ed4 SYN1deg minus Ed3 SYN1deg (200607-201112; Terra+Aqua+GEO)



- Global mean difference = 0.2 Wm^{-2}



EEI Average (2001-2015) = 0.72 +/- 0.09 Wm^{-2}

CERES: EBAF Ed2.8-TOA (adjusted to mean in-situ EEI for 2005.5-2015.5)
In-Situ: Argo ocean heating rate (0-1800 m) + deeper ocean + melting ice, warming land and atmosphere

- Extended CERES vs Argo comparison to 10 years instead of 5 years.
- Much better consistency: The error of the trend is halved from our previous estimate. Also, correlation has improved from 0.46 to 0.77.

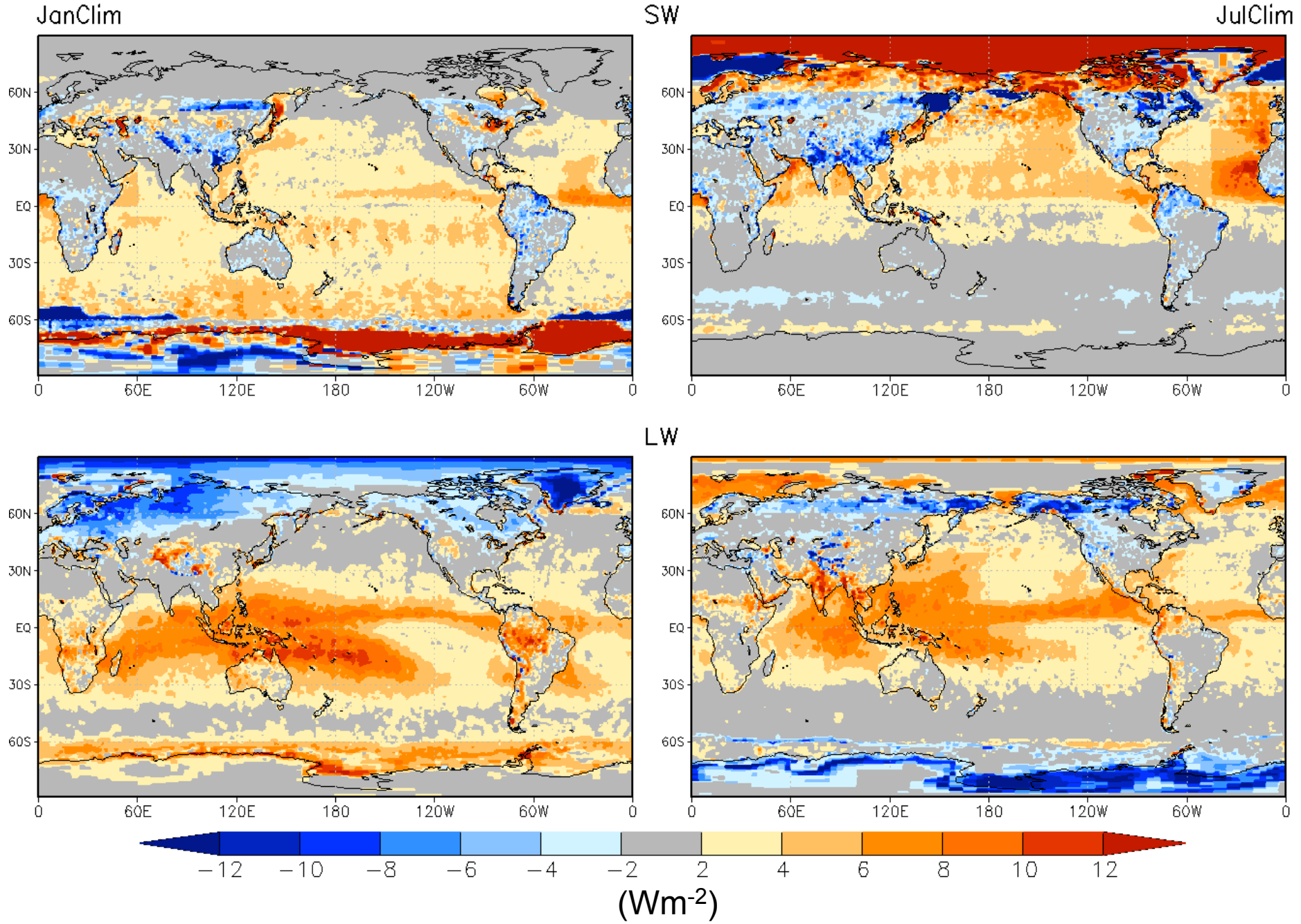
EBAF-TOA Ed 4.0 (High-Resolution Clear-Sky Fluxes)

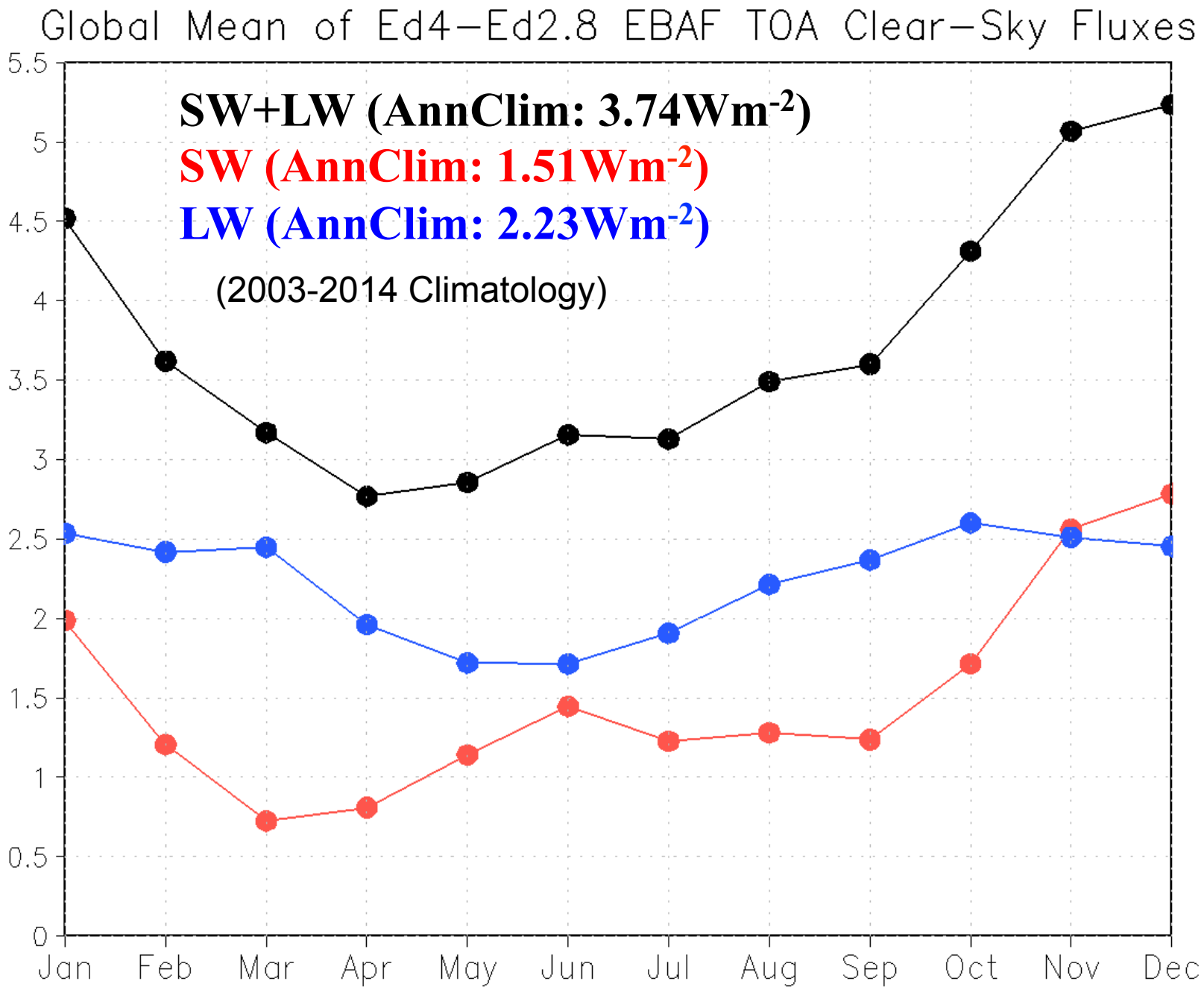
- Includes clear-sky fluxes from cloud-free CERES footprints & estimates from clear portions of partly cloudy CERES footprints.

Ed4 Improvements:

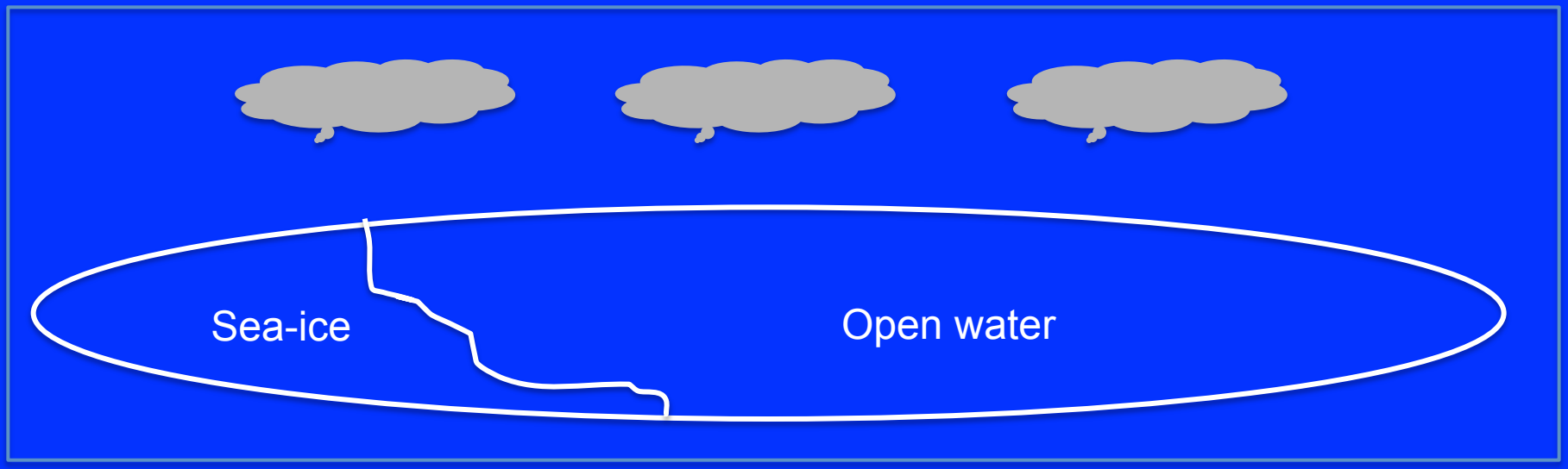
- Ed4 MODIS cloud mask & CERES ADMs (Ed4 SSF).
- New narrow-to-broadband regressions: use more MODIS bands available in Ed4 CERES SSF.
- Estimate clear-sky fluxes for footprints with partial snow and sea-ice coverage.
- Fix bug found in Ed2.8 SW clear-sky time-space averaging.
  - Ed2.8 erroneously used all-sky directional models (DMs) instead of clear-sky DMs.
- Include clear-sky area weighting of daily mean clear-sky TOA fluxes within a region when computing monthly mean clear-sky TOA flux.
  - Ed2.8 TISA algorithm treated all daily mean fluxes equally, regardless of clear-sky area coverage.
- Based upon MODIS Terra for 2000-2002; MODIS Aqua for 2002-onwards.
  - Aqua water vapor bands more stable in time than for Terra.
- GMT instead of local time.

EBAF-TOA Clear-Sky Ed4 minus Ed2.8 (2003-2014 Climatology)




Global Mean of Ed4−Ed2.8 EBAF TOA Clear−Sky Fluxes
SW+LW (AnnClim: 3.74Wm-2)
SW (AnnClim: 1.51Wm-2)
LW (AnnClim: 2.23Wm-2)
(2003-2014 Climatology)
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Clear-sky Flux for Partly Cloudy Footprints with Partial Snow/Sea-ice Cover



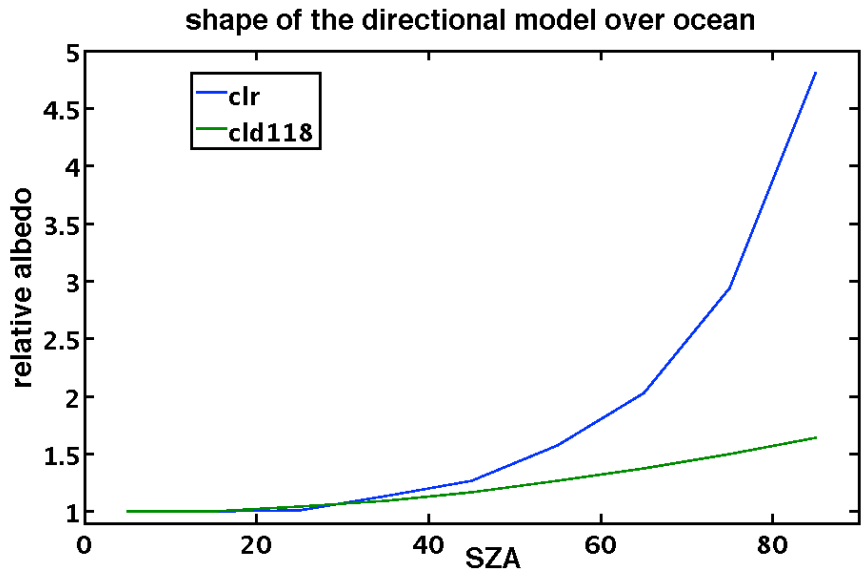
EBAF Ed2.8

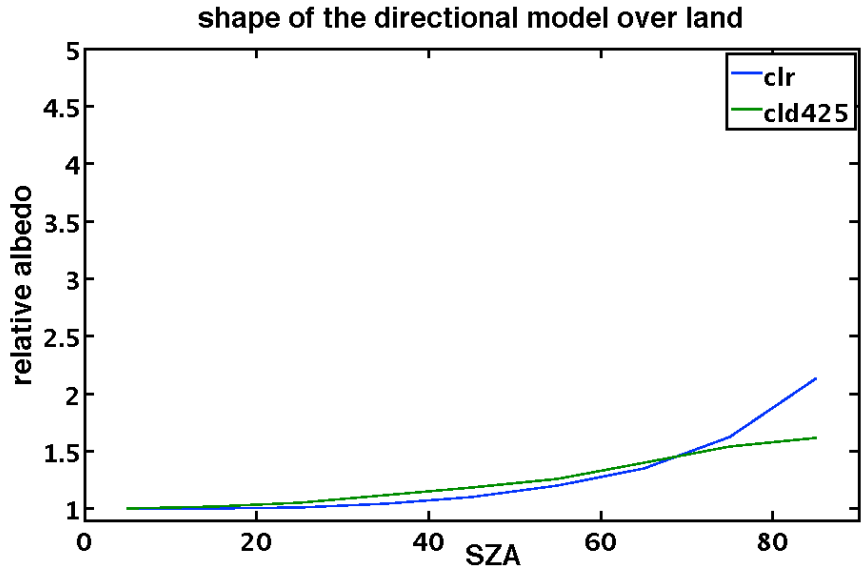
- Only estimate high-resolution clear-sky flux if FOV is partly cloudy and has 100% sea-ice, 100% open water or 100% land coverage.
  => Excludes many FOVs with high partial sea-ice coverage.
  => Clear-sky SW TOA flux biased low over summertime Arctic Ocean.

EBAF Ed4.0

- Estimate high-resolution clear-sky flux if FOV is partly cloudy and partly sea-ice/ water or partly snow/land. Apply both sets of regressions to clear-sky radiances and weight by surface type coverage.
  => Increases clear-sky SW TOA flux over Arctic Ocean compared to Ed2.8.

Influence of Incorrect Specification of Directional Albedo on 24h Average Clear-sky SW TOA flux

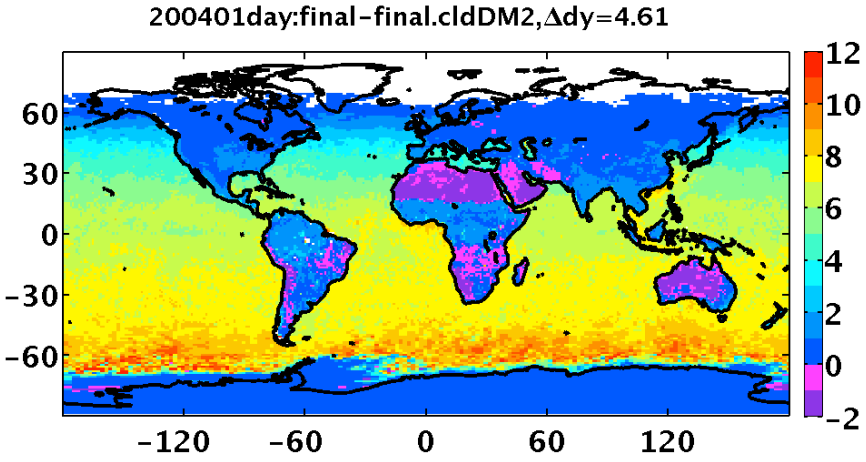


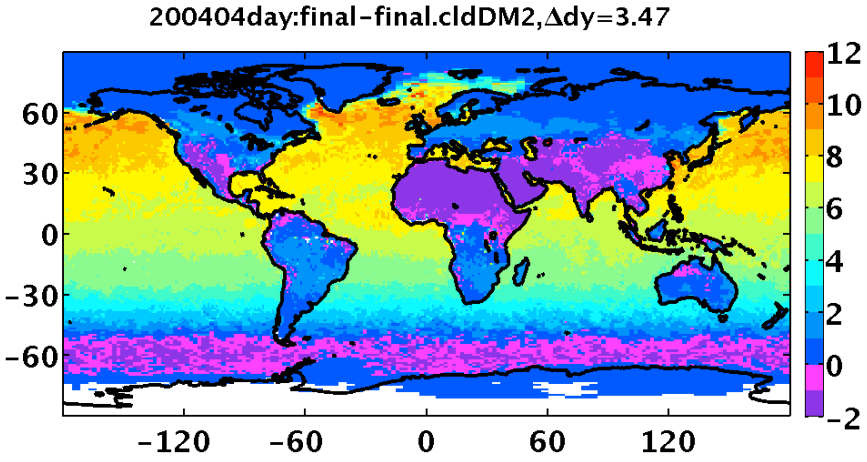


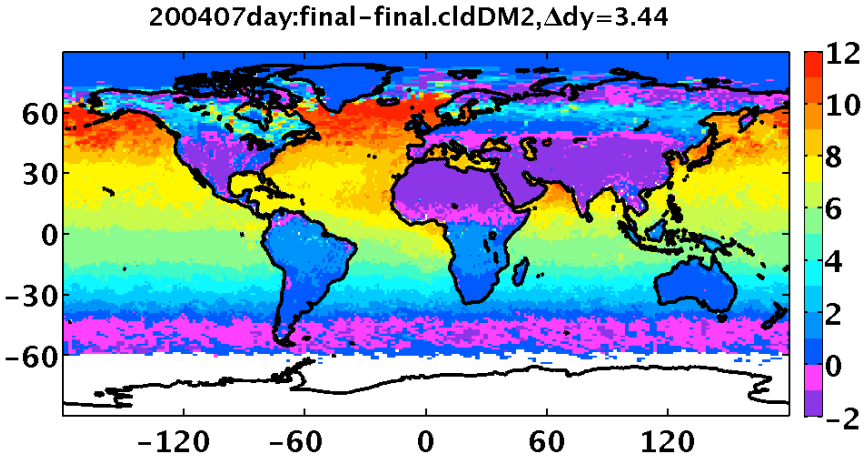
- Ed2.8 erroneously used an average all-sky directional albedo model over a region instead of clear-sky DMs.
- This causes 24h clear-sky SW TOA flux to be underestimated.
- Underestimation is greater over ocean than land.

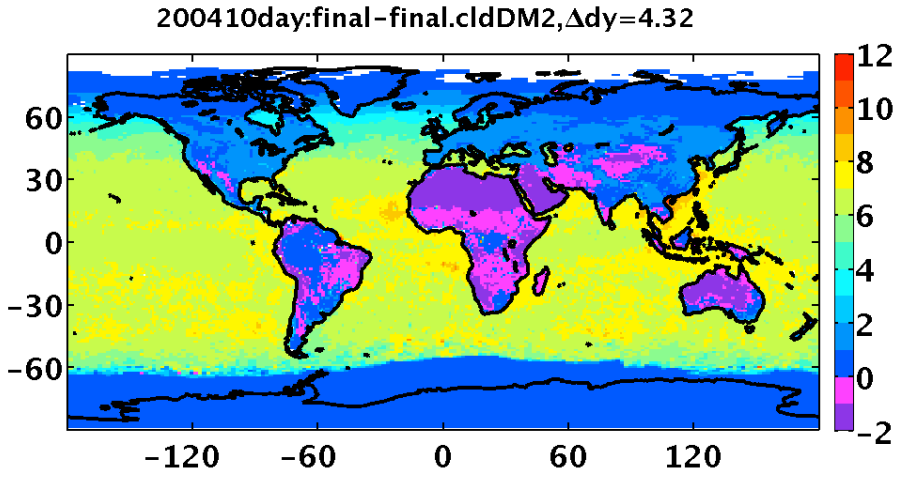
Note: directional albedos based upon CERES TRMM observations.

Diurnally Averaged High-Resolution Clear-Sky TOA Flux Difference (Using Clear-Sky vs Partly Cloudy Directional Models (DM))







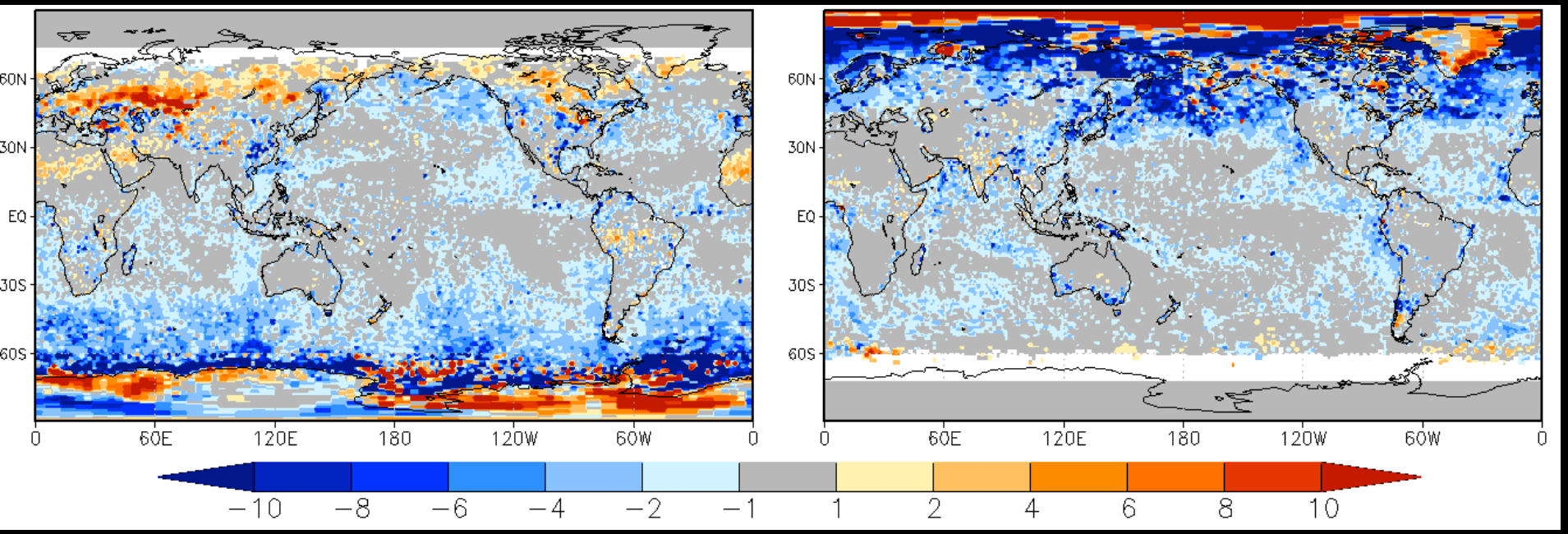


- Applying a clear-sky DM substantially increases 24-h avg SW clear-sky TOA flux relative to a partly cloudy DM.

Influence of Clear-Area Weighting on Monthly Mean Clear-Sky **SW** TOA Flux

January 2004

July 2004



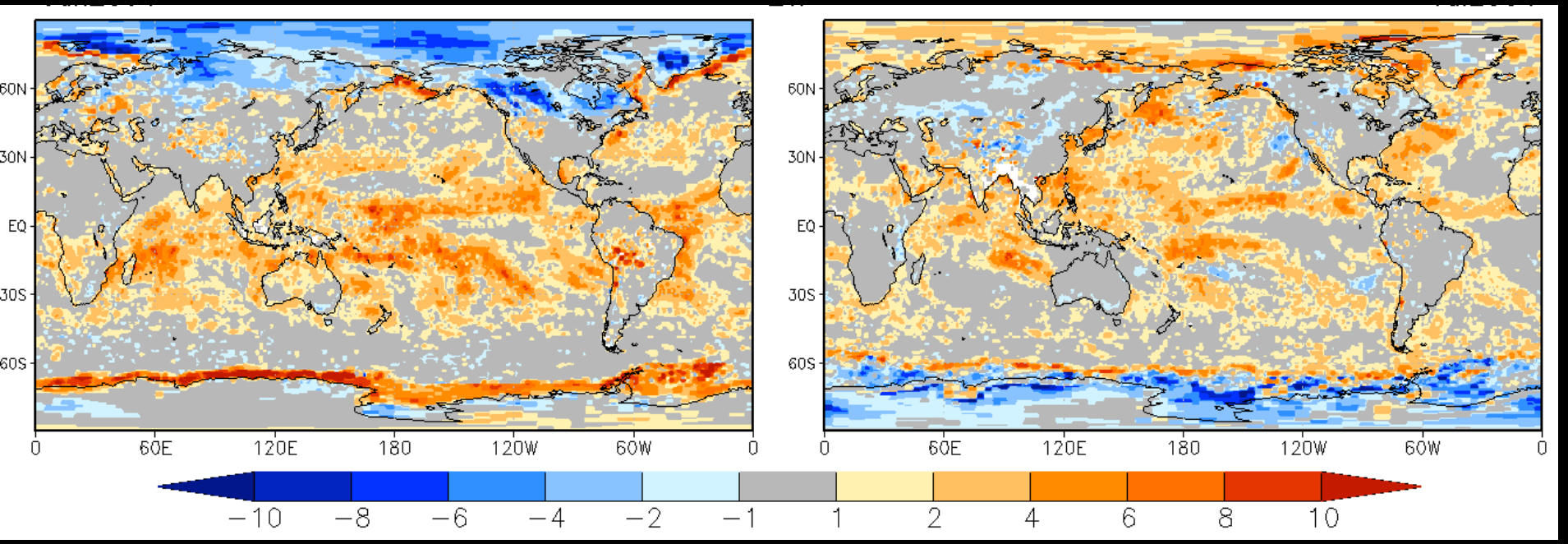
Wgt minus No-Wtg Diff (Wm^{-2})

- Including clear-sky area weighting of daily mean clear-sky SW TOA fluxes reduces global annual mean by 1.7 Wm^{-2}.
- Greatest impact in regions that are persistently cloudy (e.g., Southern Oceans; N. Atlantic & Arctic Oceans).

Influence of Clear-Area Weighting on Monthly Mean Clear-Sky **LW** TOA Flux

January 2004

July 2004



Wgt minus No-Wtg Diff (Wm^{-2})

- Including clear-sky area weighting of daily mean clear-sky LW TOA fluxes <u>increases</u> global annual mean by 0.9 Wm^{-2}.
- Greatest impact in deep tropics and high latitudes.

Summary

- EBAF Ed4 incorporates the many improvements that are part of the Edition 4 suite of CERES data products (Level 1-3).
- All-sky TOA flux differences will be relatively minor compared to Ed2.8.
  - EEI constraint will be based upon new 10-year Argo estimate.
- EBAF Ed4 Clear-sky TOA fluxes differ markedly from Ed2.8:
  - Global annual mean SW TOA flux increases by 1.5 Wm^{-2}
  - Global annual mean LW TOA flux increases by 1.9 Wm^{-2}